# Estimating the Cost of Health Care–Associated Infections: Mind Your p's and q's

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**Monetary valuations of the economic cost of health care–associated infections (HAIs) are important for decision making and should be estimated accurately. Erroneously high estimates of costs, designed to jolt decision makers into action, may do more harm than good in the struggle to attract funding for infection control. Expectations among policy makers might be raised, and then they are disappointed when the reduction in the number of HAIs does not yield the anticipated cost saving. For this article, we critically review the field and discuss 3 questions. Why measure the cost of an HAI? What outcome should be used to measure the cost of an HAI? What is the best method for making this measurement? The aim is to encourage researchers to collect and then disseminate information that accurately guides decisions about the economic value of expanding or changing current infection control activities.**

Because health care resources are scarce, they should be allocated to programs that deliver quantifiable health benefits. A rule of thumb for decision making is that the more benefit gained per dollar spent, the better [1]. This applies to those working to reduce the number of health care–associated infections (HAIs). They should aim to allocate their budget across infection prevention strategies that deliver the largest possible health benefit [2–5]. To demonstrate the "biggest bang for your buck" argument, estimates of how health benefits (the bang) and costs (the buck) change with the adoption of novel infection control interventions are required [3, 6]. That increasing investment for infection control is economically justified is not questioned. HAI is a major problem that prolongs hospital stays, prevention is relatively cheap, and many prevention strategies are effective [7]. Whether the economic argument has always been made in the best way and whether optimal analytic methods have been used to estimate the primary economic parameters are worth discussion.

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Many decisions about expanding infection control have been based on partial economic studies that show only the gross cost of an HAI [8, 9]. Costing studies may influence decision makers because the estimated gross cost per HAI has been found to be very high, and the conclusion that the cost saved from expanding infection control will exceed the cost incurred is assumed to be true without rigorous analysis. To evaluate completely a new infection control strategy requires accurate estimates of the extra cost of implementing the strategy, the cost savings from the predicted number of prevented cases of HAI, and the clinical effectiveness and health benefits. Simple costing studies that show the gross costs of an HAI are partial evaluations and provide none of this information [10]. Good decision making about infection control should emerge from cost-effectiveness research [11, 12]. Those working for infection control are publishing complete economic appraisals at a rate faster than before [13–16], and this is positive. This research often makes use of modeling studies with various pieces of information harvested from the literature. A key piece of information is the cost per case of HAI, which informs, albeit indirectly, the expected cost saving from extra infection control [17].

Data are now emerging that seriously question the validity of previously applied methods used to determine the cost of an HAI [18–25]. The main cost of an HAI is the extra stay in the hospital. Estimates of extra length of stay based on sounder statistical methods tend to show a shorter estimated extra stay, which means that the cost of an HAI may have previously been overestimated [18]. Also problematic is the method used to attach monetary value to lost bed-days, which is often based on cost accounting practices and not economic principles—yet these 2 disciplines have quite different objectives. There may be serious problems with how the economic costs of an HAI have been estimated. Given the importance of estimates of the cost of an HAI for decision making, we are motivated to discuss the approaches used. Three important questions are considered; our aim is to stimulate research that accurately guides decision making about the economics of changing current infection control activities.

## WHY MEASURE THE COST OF AN HAI?

The primary reason to understand the cost of an HAI is to inform decisions about how to reduce the problem [2–5]. Because health care resources are scarce, HAIs should be reduced by allocating resources only to efficient infection control programs. One approach is to maximize the amount of health gained from a defined pot of resources. This is called an extrawelfarist view of economics [26] and is used widely in health services decision making [27]. Other approaches to solving resource allocation problems are available [28], and their merits have been debated elsewhere [26, 29–31].

The extrawelfarist approach uses a conceptually simple rule to guide decision making. The change to cost from a decision to adopt a new health intervention (such as a novel infection control intervention) should be adequately compensated by the change to health benefit. Changes to cost are summarized in monetary terms, and changes to health benefit are normally described by means of quality-adjusted life-years (QALYs), which combine information on the quantity and quality of years of life gained [28, 32]. The number of QALYs gained from infection control demonstrate improved quality of care, because lives are saved and events that reduce the quality of life for hospital patients are avoided.

The extrawelfarist decision rule can be written as

$$\Delta C/\Delta E < \lambda \ ,$$

where $\Delta C$ is the total dollar costs under a new intervention less the total dollar costs under an appropriate comparator (usually the existing practice), $\Delta E$ is the change in health outcomes that arises from a decision to invest in a new health intervention (the total number of QALYs under a new intervention less the total number of QALYs under an appropriate comparator), and $\lambda$ is the decision maker's maximum willingness to pay for each QALY. Challenges exist for the analyst who quantifies the change to QALYs (health benefits) from infection control, and a critique of these is beyond the scope of this article. When the decision rule is met, those working under an extrawelfarist economics framework might adopt the new intervention on the grounds that it promotes efficiency. If $\Delta C = 100$, $\Delta E = 5$, and $\lambda = 30$, the rule is met and the intervention should be adopted. Finding an appropriate value for $\lambda$ is not straightforward [33]. The value varies in practice, often to accommodate other important objectives, such as equity and fairness [28]. The use of the extrawelfarist decision rule for infection control has been discussed in detail elsewhere [3].

For infection control decisions, the change in cost statistic ($\Delta C$) arises from 2 opposing forces. The first is that costs always increase with a decision to implement extra infection control strategies. The second is that cost savings arise from avoided cases of HAI. Because the cost of a case of HAI affects the value of $\Delta C$, it is important to estimate costs with accuracy. Otherwise, the $\Delta C$ statistic will be incorrect, and bad decisions may result.

## WHAT OUTCOME SHOULD BE USED TO MEASURE THE COST OF AN HAI?

The number of bed-days lost to a case of HAI is an appropriate outcome to describe a large proportion of the cost, and this number can be represented by the letter *q*. The marginal number of bed-days released by reducing the rate of HAIs may well have a positive economic value or price, which can be elicited from the appropriate source and represented by the letter *p*. A large part of the cost of an HAI is, therefore, the quantity of bed-days saved (*q*) multiplied by their economic value or price (*p*)—or *pq*. The remainder of the costs of an HAI arise from consumable items used to treat the infection and from physician fees that are billed separately. The consumables saved can result in substantial cost savings, such as when a bloodstream infection leads to septic shock. Very expensive drugs might be required and a high volume of other consumable items used. More modestly, a treatment protocol for respiratory infection due to methicillin-resistant *Staphylococcus aureus* may account for less costly consumables. It will be hard to identify exactly the extra physician fees that arise from treating an HAI, but concurrent attribution methods may be useful for this task [34].

We propose that counting the number of bed-days saved first (*q*) and valuing them in dollar terms second (*p*) is a powerful method for describing much of the economic cost of an HAI. Our reasons emerge from considering the different objectives of the hospital-based cost accountant and the public policy economist. The rest of this section is about finding a value for *p*, and the next section is about the methods used for estimating *q*.

A public policy economist would take a different approach than a cost accountant to valuing *p*. The economist would investigate the value of the bed-days in the next best alternative use and so seek the economic opportunity cost incurred from using it to treat an HAI. The accountant would estimate the cash expenditures made to supply the average bed-day. These

2 values for $p$ are likely to be different, because health care is an unusual commodity in economic terms [35]. Yet the value for $p$ is critical for decision making about investments for infection control. Those who make the argument for extra investment in infection control are making an economic argument. They wish to reallocate scarce resources toward infection control and thus away from the supply of some other health-producing activity. They must therefore consider the opportunity cost of the marginal bed-day. Using data collected by hospital accountants to find $p$ may lead to erroneous decisions about new infection control strategies. We explain the reasons for the divergent valuations of $p$ by considering the objectives of the hospital accountant and then the economist.

The hospital accountant strives to keep the organization financially viable for current and future annual budgeting cycles; the objective is to maintain a going concern [36]. In this task, hospital accountants face a high proportion of fixed costs, up to 85% [37, 38]. Examples of fixed costs are power, information and finance systems, and the salaries of many staff. They must recover all the fixed and variable costs of supplying hospital care. Variable costs are those not fixed and can be assigned to individual patients on the basis of use. For example, the number of antibiotics or bags of saline used can be counted and the cash expenditures added to a patient's bill. Fixed costs are likely to be used jointly by many patients over an annual budgeting cycle. Hospital accountants will allocate fixed costs by surrogate measures of activity—such as bed-days, tests ordered, or units of staff time—and then count the units of each measure assigned to patients. The majority of hospital costs are allocated by length of stay [39–41]. If rates of HAIs fall, fewer bed-days, tests, or units of staff time are used, but the cash expended on fixed costs will not change. The result is spare capacity in the hospital, and, unless it is redeployed for new patients, the average fixed cost recovered for every unit of activity (eg, a bed-day) will rise. Cost estimates that emerge from accounting departments are managerial costs designed to recover total expenditures for an annual budgeting cycle. They are a convenient way to keep the hospital financially viable and arise from measures of patient throughput. Accounting costs are not designed to represent the economic value of the marginal health care resources released from a reduction in the number of HAIs [42].

The economist will focus on the marginal number of bed-days and other resources released and on the cash from saved variable costs. Economists will ignore the expenditures made for fixed costs that correctly occupy accountants. These are irrelevant to any decision about allocating scarce resources for new infection control strategies, because they will not change with lower rates of HAIs. The marginal number of bed-days released by infection control may, however, take a positive economic value in some other use. They can be used to increase productivity and treat more patients. Their opportunity cost is the value that someone is willing to pay to access the marginal bed-day. As long as the effective demand exceeds the supply for hospital-based services, then marginal bed-days will be valuable items in economic terms.

In a decentralized system (such as in the United States), the next patient or his or her insurance company may be willing to pay a certain price ($p$) to access the bed-days released by the positive effect of extra infection control. In a centrally managed health care system (such as the UK National Health Service) that is owned by the public sector, politicians and bureaucrats can be asked their willingness to pay for hospital bed-days given other demands on public sector spending. One scenario is that there is zero demand for newly released bed-days, so their opportunity cost is zero (ie, $p = 0$). This is unlikely when we consider the long waiting lists and large pool of unmet health needs in almost every jurisdiction. If opportunity costs are positive, then the value is likely to vary. Local demand conditions may play a role. If patients face long waiting lists for elective admission, there are demands for higher throughput by hospitals, and no new building programs are planned to increase supply, then marginal bed-days may be valued higher than in a jurisdiction with less severe constraints. The perspective of the person making the valuation may also play a role. If an election is looming and a politician has promised to improve health care services by treating more patients in hospitals and reducing waiting lists, he or she will put a high value on extra bed-days. If, however, the chief executive of the hospital believes that adequate compensation for any extra patients admitted will not be provided, he or she may see only an increased workload and level of stress for the hospital's staff and so attach a lower economic value to bed-days released. This view will, of course, be tempered by a desire to provide high-quality services, and this improvement in quality is described by the gain in health benefits (QALYs) used in cost-effectiveness research.

## WHAT IS THE BEST METHOD FOR MAKING THIS MEASUREMENT?

Because costs are strongly dependent on length of stay, we need to accurately measure the extra length of stay caused by a case of HAI ($q$). Any method used should account for the fact that HAIs arise at different times during a hospital stay in different patients and that other factors influence length of stay, such as primary diagnosis and comorbidity. A seminal article on methodology [34] compared physician assessment with matched cohort studies, where infected patients are matched with uninfected control subjects on variables thought likely to cause an excess stay. Physician assessments provide the ideal measure but are time-consuming; matched cohort studies are easier to conduct but suffer from 2 sources of bias. The first bias arises because some patients are predisposed to a long hospital stay regardless of HAI status, and matching on confounding variables is not able to control all the bias. The second bias arises from increasing the number of matching variables in an attempt to control the first bias, as this often causes infected individuals to be selected out of the study because the pool of uninfected control subjects is exhausted. In matched cohort studies, one can only find the best tradeoff between these 2 biases; they cannot be simultaneously eliminated [6].

The time-varying nature of infection also discombobulates a matched cohort study [19]. Exposure to an HAI can occur at any point during a hospital stay, but matched cohort studies tend to compare infected and uninfected patients by their total hospital stay. Infected patients can start generating costs due to an HAI only after the infection has begun. If the timing of events is ignored, costs that manifest before the HAI are included. Combining preinfection outcomes with postinfection outcomes can dramatically amplify confounding [19]. This bias is often called *time-dependent bias*, and it has been shown mathematically to always overstate the prolonging effect of an HAI on length of stay [21]. Another closely related problem is a feedback effect between an HAI and length of stay. Methods that fail to account for this issue will produce biased estimates of extra length of stay ($q$). Despite these severe limitations, matched cohort studies remain the most commonly used method for estimating cost and produce heterogeneous results [6].

Methods that are less labor intensive than physician assessment and that are methodologically superior to matched cohort studies can be used; however, they are technically complex. Most promising are statistical models that control for differences between patients at the analysis stage rather than at the design stage. A statistical model can be built to describe the relationship between a cost outcome, such as length of stay in the hospital, and predictors of that outcome [43]. An advantage is that multiple predictors can be included without selecting out cases of HAI [24]. Statistical models, such as event history analysis or survival analysis, can be used to account for the time-varying nature of infection. They model the hazards or rates between hospital admission, potential onset of HAI, discharge alive from the hospital, and death in the hospital. Additional time-dependent information, such as daily intubation status, may also be included. Methods for both discrete and continuous time are available [18, 44] and have their merits, which we will not discuss here. These methods have been applied and show extra lengths of stay that are substantially lower than those from methods that do not account for the timing of events and important covariates [18, 45–47].

## CONCLUSION

The "HAI costs a lot" approach to influencing decision making has served the infection control community well. Important articles have stated that very large costs arise from HAIs [38, 48–50]; all have been cited frequently and used to attract resources toward infection control programs. The time has arrived, however, for the methodological advances that have been achieved in this area to be implemented by researchers. Complete economic evaluations that include changes to all costs and health benefits should be performed. The information used to update these studies should be of high quality and bias free. Those working in other areas of disease are using state-of-the-art research methods to successfully make economic arguments for increased spending. Examples include cost-effectiveness analyses of different screening methods for colon cancer [51], of interventions that improve physical activity [52], and of screening for osteoporosis and treatment with hormone-replacement therapy [53].

Inexorable growth in health care costs is forcing decision makers to respond to scarcity and work toward extracting greater value from health care resources. The United States, Switzerland, France, Germany, Belgium, Portugal, Austria, and Canada all devote >10% of their gross domestic product to health spending [54]. The time when reliable economic arguments will be paramount for obtaining extra resources—and even retaining existing ones—is close. Those working toward reducing the number of HAIs should craft valid economic arguments on the basis of sound methods and use them to build strong and cost-effective infection control programs.

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